Edited by Bill Travis

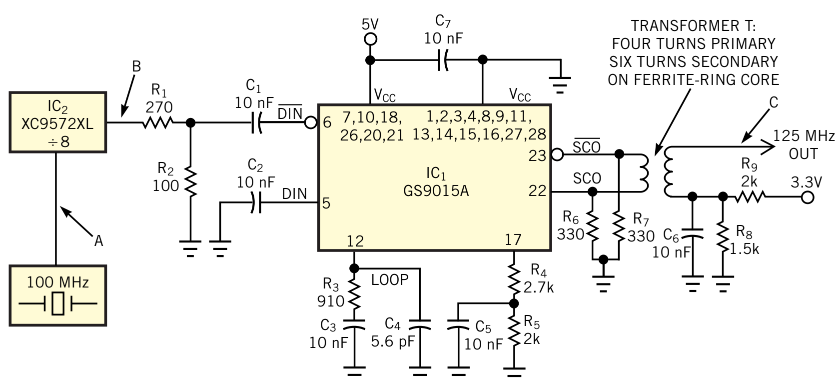
Circuit allows high-speed clock multiplication

Lukasz Sliwczynski and Przemyslaw Krehlik, University of Mining and Metallurgy, Krakow, Poland

In theory, synchronous clock multiplication is an easy task. A simple PLL with two digital dividers—one inserted just after the VCO (voltage-controlled oscillator) and the second one placed directly at the input of the phase detector—may do the job. The flexibility of such a configuration allows for clock multiplication by any rational number. However, a problem emerges if you want to multiply a high-frequency clock. Standard, integrated PLLs, such as the 74HC/HCT4046 and NE564, do not accommodate such fast clock signals; they're limited to frequencies lower than approximately 60 MHz for the NE564. Although you can implement almost all PLL subcircuits by using fast programmable logic, such as CPLD or FPGA circuits from Xilinx (www.xilinx.com), a big problem exists in providing the proper high-frequency VCO. Two obvious possibilities exist: Order the VCO from a company specializing in high-frequency circuits, or build it yourself. The first approach can be costly; the second requires specialized knowledge and can be frustrating for an inexperienced designer. The circuit in **Figure 1** offers yet another possibility.

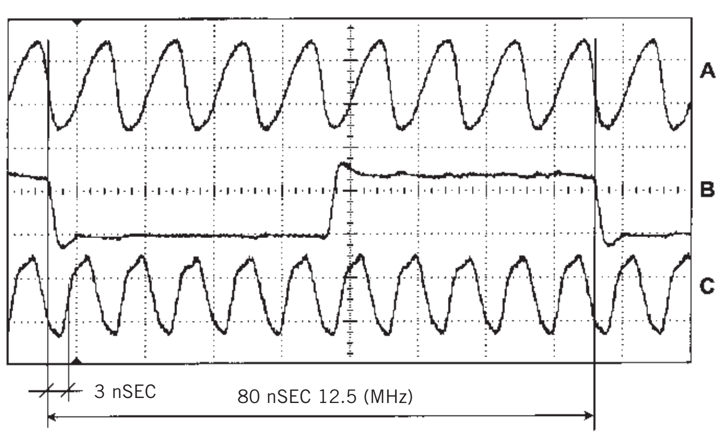
Publish your Design Idea in *EDN*. See the What's Up section at www.ednmag.com.

Figure 1



Using this simple circuit, you can easily and cheaply multiply high-frequency clock signals.

Figure 2



This scope photo shows some key waveforms in the circuit of Figure 1.

The circuit is based on IC_1, Gennum Corp's (www.gennum.com) GS9015A clock-recovery IC, an ECL-based circuit that can operate at frequencies to approximately 400 MHz. You normally use such an IC to extract clock information from a digital NRZ data stream with the aid of an input divider. The clock-recovery circuitry is in principle a form of PLL with a special type of digital phase comparator. The comparator allows for VCO phase adjustment only when high-to-low or low-to-high transitions are present in the input signal. This property of the clock-recovery circuit allows you to exploit it as a clock multiplier. If you apply a signal with 50% duty cycle instead of a normal NRZ data stream to the input of the clock-recovery circuit, the circuit attempts to interpret the signal as a sequence of N consecutive zero and one symbols and controls its VCO in such a way as to produce a clock transition for each symbol. The result is a multiplication of the input frequency by the factor 2N. You set the actual multiplication coefficient by setting the VCO's free-run frequency close to the desired output clock frequency. To avoid locking of the clock-recovery circuit to some undesired multiplication coefficient, you should make the VCO's tuning range narrow.

This design is applied to a 4B5B encoder, which needs to derive a 125-MHz clock from a 100-MHz master-clock signal; therefore, it needs a multiplication factor of 5/4. To realize this operation, you must first divide the 100-MHz clock by 8 and then multiply the result by 10. (Note that only even multiplication coefficients are possible using the concepts in this Design Idea.) **Figure 2** shows some key waveforms the circuit produces. The complete design implements the remaining part of the encoder with IC_2, a 3.3V XC9572XL CPLD IC to match logic levels. Resistor R_3 and capacitors C_3 and C_4 form the loop filter, and resistors R_4 and R_5 set the free-run frequency of the VCO. The circuit in **Figure 1** is simple and easy to build. The only trimming it requires is the initial setting of the VCO's free-run frequency (close to 125 MHz). You perform this trim by observing the output waveform with an oscilloscope and adjusting variable resistor R_5 with R_2 shorted.

Is this the best Design Idea in this issue? Select at www.ednmag.com.

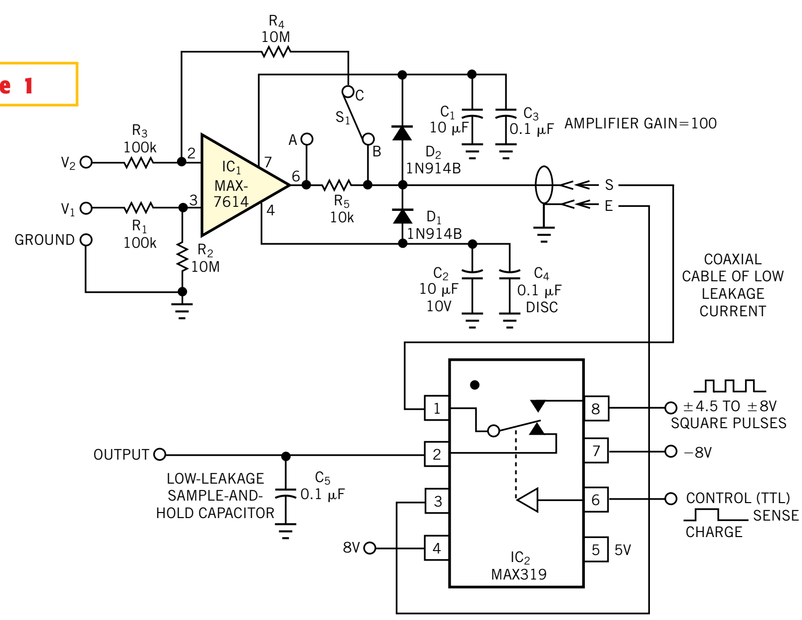
Differential amp needs no power source

Shyam Tiwari, Sensors Technology Private Ltd, Gwalior, India

A TRUE-DIFFERENTIAL, power-source-free, high-input-impedance amplifier with bipolar output would present distinct advantages in remote devices. Such an amplifier, with its bipolar output, would be a better choice than a unipolar, 4- to 20-mA device. It would also improve on common-mode performance. In **Figure 1**, a Maxim MAX319 analog switch, IC_2, feeds the power from the coaxial signal cable to the charge-holding capacitors, C_1 and C_2. The analog switch injects both positive- and negative-polarity signals into the charging circuit when its Control signal has a high (TTL) level. At the same time, the output uses a sample-and-hold capacitor to retain the last analog signal during the charging cycle. Thus, the circuit never loses the signal, as long as the charging and sensing cycles maintain timing within certain limits.

You can increase the values of C_1 and C_2 if the sensing time is considerably greater than the charging time. Switch S_1 places the feedback resistor, R_4, either in a direct connection to the sample-and-hold capacitor, C_5, or before R_5 to form an R_5-C_5 lowpass filter. In either case, R_5 is a protective resistor during the charging period, ensuring 10-kΩ load resistance for IC_1, a low-bias-current, low-power MAX7614 amplifier. This amplifier is an improved version of the ICL7611. This amplifier circuit was useful for thermocouple-signal amplification without cold-junction correction. You can also use it for bipolar, low-current signal amplification with a range of ±10 pA to ±1 nA, using only R_4 for the current-to-voltage conversion.

Figure 1



A high-impedance differential amplifier is useful in remote locations, because it requires no local power supply.

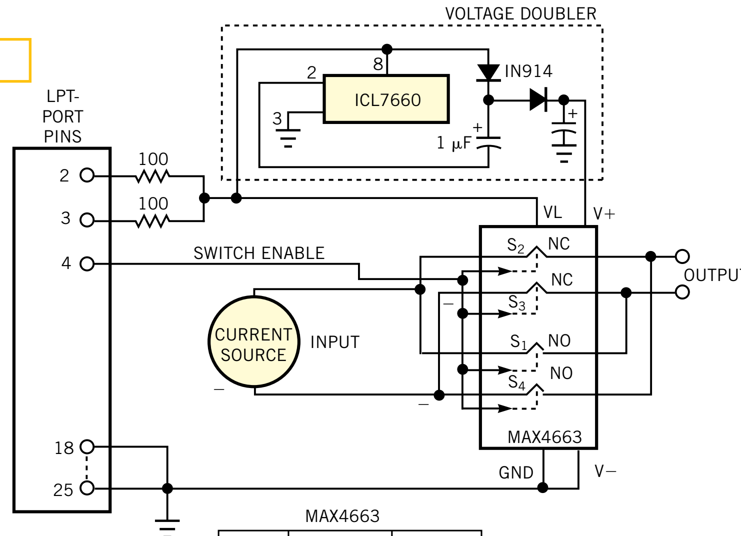
Is this the best Design Idea in this issue? Select at www.ednmag.com.

Printer port activates CMOS switches

J Jayapandian, IGCAR, Tamil Nadu, India

THE COST-EFFECTIVE design in **Figure 1** provides control for CMOS switches without the need for an external power supply. Analog switches such as those in the MAX4663 are ideal for use in low-distortion applications. They are preferable to electromechanical relays in automatic test equipment or other applications in which you need current switching. The CMOS switches use lower power, consume less board space, and are more reliable than electromechanical relays. The MAX4663 quad switch features 2.5Ω maximum on-resistance, 5-nA maximum leakage current at 85°C, and −56-dB off-state isolation at 1 MHz. They also offer break-before-make switching. The switches operate from a 4.5 to 36V supply or from dual ±4.5 to ±20V supplies.

Figure 1



MAX4663

LOGIC	S_1 AND S_4	S_2 AND S_3
0	OFF	ON
1	ON	OFF

The LPT port powers a current-reversal circuit, using CMOS analog switches.

In **Figure 1**, the switches mount in and derive power from the PC's LPT port. The design provides as much as 50 mA of current, with current-source compliance as high as 10V. The circuit uses a simple voltage-doubler circuit, the negative-voltage-converter ICL7660, for the separate V^+ supply and the V_L logic supply. The current source can supply as much as ±200 mA at 10V. **Figure 1** shows a current-reversal application in a low-temperature-resistivity experiment. The design draws only a few tens of microamperes from the PC's parallel port. The MAX4663 CMOS switches have complementary pairs (normally open and normally closed). This configuration simplifies the design, with single-enable-bit operation (the switch-enable inputs are shorted together as a single enable). You can download a LabView Virtual Instrument program from the Web version of this Design Idea at www.ednmag.com. The program latches the LPT1 port at the address 0x378 with data for forward and reverse operation of the switches. At the LPT port, the D0 and D1 bits (pins 2 and 3) power the circuit in **Figure 1**. Bit D2 (pin 4) sets the switch-enable/disable function. For data word 0x03, bit D2 is low, enabling the normally open contacts; for data word 0x07, and D2 goes high, enabling the normally closed contacts.

Is this the best Design Idea in this issue? Select at www.ednmag.com.

Circuit improves on temperature measurement

Alexander Bell, Infosoft International Inc, Rego Park, NY

WHEN CURRENT PULSES with a stable I_{HIGH}/I_{LOW} ratio modulate a semiconductor junction, the ensuing voltage difference (for example, ΔV_{BE} for a bipolar transistor) is a linear function of the absolute (Kelvin) temperature, T. You can use this truism to make accurate temperature measurements. Technical literature has thoroughly covered the relationship (**references 1** to **4**) and has numerous implementations. This Design Idea suggests some areas for improvement and design variations on the basic idea. The principal equation describing the phenomenon is as follows: $\Delta V = 86.4 \times T \times \ln(I_{HIGH}/I_{LOW})$, expressed in microvolts. Setting the current ratio $I_{HIGH}/I_{LOW} = 10$ results in ΔV of approximately 200 µV per degree. The key issue in the practical implementation of the idea is to switch current with a highly stable I_{HIGH}/I_{LOW} ratio, which you can do by using a number of discrete components. This Design Idea suggests a digitally controlled and integrated approach (**Figure 1**).

The current switching with a stable

I_{HIGH}/I_{LOW} ratio, comes from a DAC with current outputs. The typical DAC has two current outputs—a direct I_1 and a complementary I_2. These outputs allow for simultaneous dual-channel temperature measurements. The current ratio I_{HIGH}/I_{LOW} is a function of the input digital code, D_I; you could program this code using a microcontroller. Obviously, you can use the circuit for single-channel temperature measurements, by simply ignoring the second output. If you need more than two channels, then use additional DACs or use a multiphase DAC (**Reference 5**). The circuit in **Figure 1** works as follows: The output currents, I_1 and I_2, are functions of the input digital code, D_I, and the input voltage, V_{IN}:

$$I_1=(V_{IN}/R_{EQ})\times(D_I/2^N), \text{ and}$$
$$I_2=(V_{IN}/R_{EQ})\times(2^N-D_I)/2^N,$$

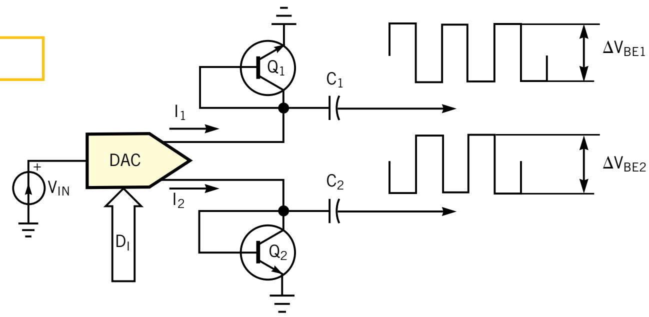
where R_{EQ} is the equivalent transfer resistance of the DAC, and D_I is the decimal equivalent of the input binary code.

The full measurement cycle consists of two phases, switching codes from D_1 to D_2. Assuming $D_1>D_2$, then the current ratio I_{HIGH}/I_{LOW} for output I_1 is equal to D_1/D_2. The current ratio for the second output I_2 is equal to $(2^N-D_2)/(2^N-D_1)$. For a 10-bit DAC (N=10), choosing $D_1=931$ and $D_2=93$, the ratio I_{HIGH}/I_{LOW} on both outputs is 10.01, which is close to the "standard" (**references 3** and **4**). For an 8-bit DAC, these numbers are $D_1=233$ and $D_2=23$, which results in a ratio $I_{HIGH}/I_{LOW}=10.13$ on both outputs. It's important that the ratio be substantially immune to variations in the input voltage, V_{IN}. Thus, any unregulated voltage source is suitable for the circuit. The source needs only short-term stability during the measurement cycle. Besides, many modern DACs integrate on-chip voltage references.

You should note that other I_{HIGH}/I_{LOW} ratios are applicable. Moreover, in general, it is unnecessary to have the same current ratios for both outputs. Thus, you could set the sensitivity to different values for the two channels. Higher ratios result in greater sensitivity, but self-heating effects impose certain limitations on I_{HIGH}, and noise levels set a lower limit on I_{LOW}. Thus, 100 and 10 μA are typical values for general-purpose bipolar transistors. As most general-purpose R-2R DACs have R_{EQ} of 10 to 100 kΩ, you should choose the proper value for V_{IN} (typically 2.5 to 10V). Alternatively, to obtain the desired I_{HIGH}, you could use an additional series resistor, R_S (not shown in **Figure 1**), connected between the voltage source and the DAC input. The R-2R ladder has an equivalent input resistance, R, which does not change with the digital code. With the additional series resistor, the equivalent transfer resistance becomes $R+R_S$. Note that this series resistor may be of almost any type, because its impact on the current ratio's accuracy is limited.

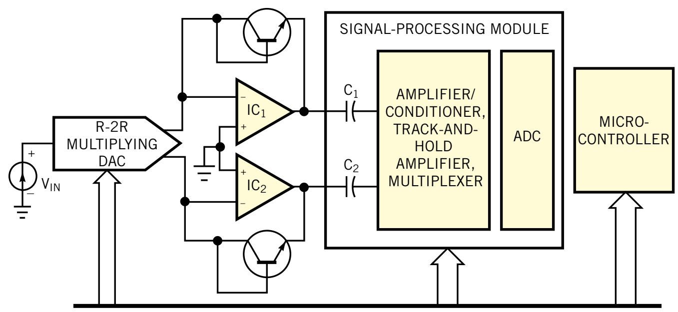
In a practical implementation, you should take into consideration the finite value of V_{BE} on the DAC's output, because its variation with temperature could affect the accuracy of the measurement. If the DAC has internal current sources, you can use the circuit of **Figure 1** as-is, because the V_{BE} has a limited effect on the current ratio. In the case of using an R-2R DAC, the circuit in **Figure 2** is more appropriate. The two op amps, IC_1 and IC_2, maintain virtual grounds on both current outputs, thus preserving the high accuracy of the current ratios. The rest of the circuit in **Figure 2** performs ΔV_{BE} measurements. You can implement that portion of the circuit by using an amplifier/conditioner, a track-and-hold amplifier, and an ADC controlled by any general-purpose microcontroller. **References 3** and **4** offer hints on implementation.

Figure 1



The DAC modulates transistors Q_1 and Q_2 with its two current outputs; ΔV_{BE} is a linear function of absolute temperature.

Figure 2



The two op amps, IC_1 and IC_2, provide virtual grounds for both current outputs of the DAC.

References

1. Belousov, Alexander, "Temperature Measurement Device," SU Author Certificate 1599674, registered June 15, 1990.
2. Belousov, Alexander, "Temperature Measurement Device," SU Author Certificate, registered May 1, 1991.
3. Steele, Jerry, "Sense temperatures without Calibration, *Electronic Design*, may6 13, 1998, pg 130.
4. Setton, Joel, "Multichannel temperature measurement system," *Electronic Design*, July 10, 2000.
5. Belousov, Alexander, "Multiphase DAC modifies R-2R lader," *EDN*, Jan 18, 1996, pg 87.

Is this the best Design Idea in this issue? Select at www.ednmag.com.

Add voice commands to your CAD system

Alexander Bell, Infosoft International, Rego Park, NY

THE FIRST TIME I ACTIVATED the Language Bar (Speech Tools) in my Microsoft Word 2002 and started dictating this Design Idea, the on-screen title displayed "cat" instead of "CAD." By using the "Add/Delete Words" feature, I've trained the system to recognize the "CAD" acronym. This was my first experience with the MOSR (Microsoft Office Speech Recognition) tool, which is part of the latest Microsoft Office XP package. Its main operational modes are dictation and voice command. This Design Idea shows how to add a practical VCI (voice-command interface) to the simple CAD system inherent in MS Word 2002 applications. **Reference 1** described a simple version of such a CAD for schematic entry. You can download some macros from the Web version of this Design Idea from www.ednmag.com. The macros, grouped and stored in the MyCAD.dot file, extend CAD functions:

- Module "mod_View" contains macros to set the drawing environment.
- Module "mod_Symbol" contains macros to perform operations on Symbol objects.

The next level of CAD-system improvement is to add the custom VCI, enabling you to run macros via voice commands. Before use, the system prompts you to use the "Voice Training" session, which lasts approximately 15 minutes. As you read the text on the screen, the system analyzes your verbal patterns to build the Default Speech Profile. A longer session results in greater accuracy of speech recognition. The "Add/Delete Words" feature enables the MOSR engine to recognize special terms and technical jargon. Formatting the title provides a good example of practical use of the MS Word 2002 built-in Voice Commands, which correspond to its Menu and Toolbars buttons' Text. First, I selected the whole sentence by saying "select all," then I converted it to boldface by saying "Bold." Then I changed the font to Arial by saying "font," and, when the drop-down menu appeared, I pronounced "Arial."

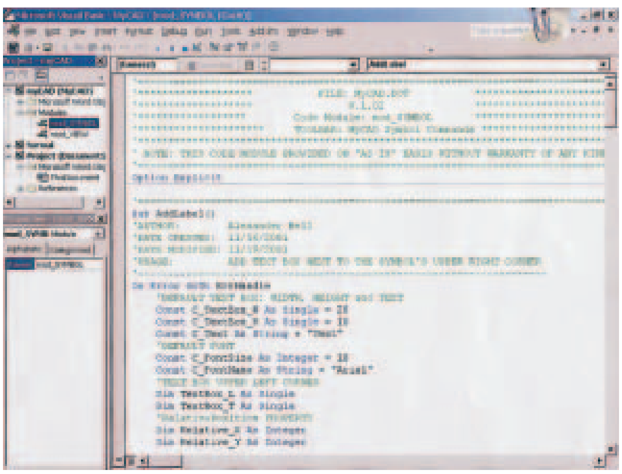


Figure 1 This Visual Basic Editor screen has the template file MyCAD.dot with two standard modules.

Finally, I set the font size to 14 points by saying "font size" and then "14," and I then underlined the title by saying "underline." You can add custom VCI by following several steps:

First, start MS Word 2002 and open a new file. Go to the Visual Basic Editor screen (shortcut: Alt+F11); add two standard modules, "mod_View" and "mod_Symbol"; and copy the macros you downloaded to the appropriate modules. The screen should look like the snapshot in **Figure 1**. From the "Debug" menu item, select "Complete Project", and then close the Visual Basic Editor window and save the file under the name "MyCAD.dot" using the "Save As" menu option. Add a custom toolbar by selecting from the menu "Tools—Customize—Toolbars—New." When a prompt appears, type the name for the new toolbar as "MyCAD Symbol Commands" and make it available to "MyCAD.dot." Add toolbar buttons related to the macros stored in MyCAD.dot. For each button, edit the button text; it defines the Custom Voice Command. The toolbars should finally look like the snapshot in **Figure 2**. Save the file and close MS Word 2002. You can consult Microsoft Office Help utility for more details on how to add custom toolbars and buttons.

Put the file MyCAD.dot into the MS Word or MS Office start-up directory. Typically, the path is "C:\Program Files\Microsoft Office\Office10\Startup." Then, start MS Word 2002, enable the macros in MyCAD.dot upon the system prompt, open a new document, and test

TABLE 1—VCI-TEST RESULTS (100 SAMPLES PER COMMAND)

	Voice commands	Correct execution	Nonrecognized	Misinterpreted
Custom commands	Grid lines	100	0	0
	Add labels	100	0	0
	Flip horizontal	100	0	0
	Increase	100	0	0
	Reduce	100	0	0
	Rotate right	99	1	0
Built-in commands: menu and toolbars-button text	File	100	0	0
	Edit	99	1	0
	View	99	1	0
	Insert	100	0	0
	Tools	100	0	0
	Help	98	2	0
	Bold	95	4	1
	Underline	100	0	0
	Cancel	100	0	0

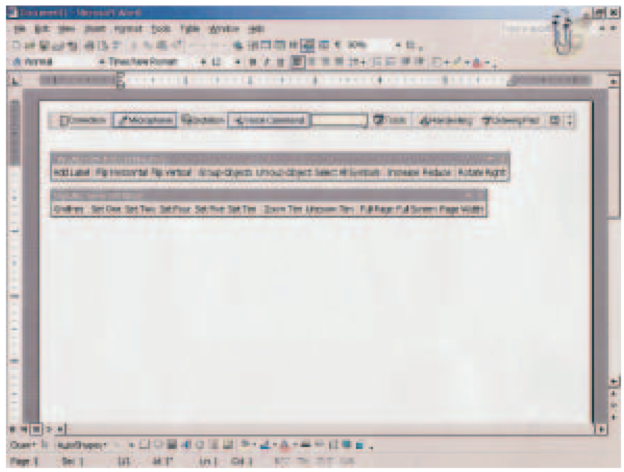


Figure 2

A Microsoft Word 2002 display has a language bar and two custom toolbars.

the VCI with both built-in and custom voice commands. It's advisable to use a set of highly phonetic, distinctive words or phrases for VCI. If not, distortion and noise can lead to misinterpretation of the voice command by confusing it with another voice command. I tested the CAD with a VCI on a PC clone with a 600-MHz Athlon CPU. The system has 256 Mbytes of SDRAM-133 and runs Microsoft Office XP Professional under the Windows 2000 operating system. The voice-command execution delay is approximately 1 sec. For faster execution, you can use a faster CPU. For audio input, this design uses an inexpensive multimedia microphone. **Table 1** shows sample test results for both built-in and custom commands.

The accuracy increases to almost 100% for the sample set of commands when you use a Plantronics (www.plantronics.com) headset with noise-cancellation features that comes with Microsoft's SideWinder game package. For more information on natural-language input technology in Office XP, refer to Microsoft Guidelines on the Web. The Web site has a link, "Hardware Guidelines for Speech Technologies." Note that, when you enable macros in MS Word or other applications, some macros could cause harmful actions, and some may contain viruses. You use the macros at your sole risk without warranties. To use the macros in the "mod_Symbol" section, you should uncheck the box "Automatically create drawing canvas when inserting AutoShapes." Go to the tabbed Dialogue: "Tools—Options—General."

Reference

1. Bell, Alexander, "Add CAD functions to Microsoft Office," *EDN*, March 21, 2002, pg 94.

Is this the best Design Idea in this issue? Select at www.ednmag.com.